CRITICAL MINIMUM BODY TEMPERATURES OF *HOPLODACTYLUS MACULATUS* (REPTILIA:GEKKONIDAE) FROM NEW ZEALAND

M.D. TOCHER

Zoology Department, University of Canterbury, P.O. Box 4800, Christchurch, New Zealand

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ABSTRACT

Tocher, M.D. (1993) Critical minimum body temperatures of *Hoplodactylus maculatus* (Reptilia: Gekkonidae) from New Zealand. *New Zealand Natural Sciences* 20: 41-45.

Critical minimum body temperature (CTMin) was determined for *Hoplodactylus maculatus* collected from two areas differing with respect to climate; Banks Peninsula (warm climate), and Craigieburn (cold climate). The CTMin was lower in winter than summer for both populations (summer values 1.6±0.1°C and 1.9±0.2°C and winter 1.0±0.1°C and 0.8±0.2°C, Banks Peninsula and Craigieburn respectively, $P<0.05$). No significant difference in CTMin between populations was found for geckos collected fresh from the field (winter and summer), or following various acclimation treatments. However, cold treatment (winter and long-term 5°C acclimation) significantly lowered CTMin in both populations ($P<0.05$).

KEYWORDS: *Hoplodactylus maculatus* - gecko - Critical - thermal minimum - acclimation - acclimatization - New Zealand

INTRODUCTION

Few workers have attempted to explain reptile distributions and speciation in cold regions (but see Saint-Girons & Saint-Girons 1956, Jacobson & Whitford 1970, Prieto & Whitford 1971, Spellerberg 1971,1972). From an ecological standpoint, an ectotherm's critical thermal minimum (CTMin) is equivalent to it's lethal minimum, since this is the temperature that causes cold narcosis, and effectively prevents locomotion. Thus CTMin is a useful indicator of the adaptation of animals to differing climatic environments. It is widely accepted that a reptile's CTMin is the body temperature at which the animal has just lost its righting reflex and locomotory ability after cooling (Wilson & Echternacht 1987, Kaufmann & Bennett 1989). At this temperature animals are helpless to escape enemies or to remedy their thermal impasse (Cowles & Bogert 1944).

Variables known to affect CTMin include seasonal patterns, daily rhythms, climatic influences and laboratory procedures such as rate of cooling (Spellerberg 1973). A seasonal lowering of CTMin may be associated with low ambient temperatures (Spellerberg 1972). Spellerberg (1972, 1976) examined the thermal relations of 29 Australian lizards and found that the fastest rate of acclimation of CTMin occurred at body temperatures 1°C below the CTMin of field collected specimens. Furthermore, Spellerberg & Hoffmann (1972) found a small but significant endogenous daily circadian variation in CTMin, peaking at the end of the activity phase.

With respect to climatic influences, Jacobson & Whitford (1970) found the CTMin of the more northerly distributed northern hemisphere snake *Thamnophis proximus* (Colubridae) was lower than that of *Natrix rhombifera* (Colubridae) a more temperate species. Similarly, Prieto & Whitford (1971) reported the CTMin of the desert-dwelling lizard *Phrynosoma cornutum* was 9.4°C, whereas that of *P. douglassi*, the distribution of which extends to an altitude of 3494 m, was only 2.7°C. Spellerberg (1972) concluded that the CTMin was a valuable concept in reptilian ecology and physiology that correlated well with the distribution of lizards throughout Australia.

Recent electrophoretic work has shown that *Hoplodactylus maculatus* (Reptilia: Gekkonidae) may in fact be a species complex of four species

(Hitchmough 1991). The aim of the present study was to determine whether two geographically isolated populations of *H. maculatus* living in different climatic regimes had different thermal minima (Tocher 1992a,b). The only previous intraspecific comparison of critical thermal minimum was made on *Anolis carolinensis* by Wilson & Echternacht (1987) in the southern United States.

MATERIALS AND METHODS

STUDY SITES AND ANIMALS

Only adult male geckos (5.0-10.0 g) were collected by hand from rock outcrops at two South Island localities: Castle Hill Basin (Craigieburn) approximately 80 km inland from Christchurch, and Teddington on Banks Peninsula, New Zealand (see Tocher 1992b for locality map). Castle Hill Basin lies at an altitude of approximately 900 m a.s.l. and a latitude of 43°09'S. Frost days during the summer growing season are common. The Banks Peninsula site is approximately 50 m a.s.l. at a latitude of 46°19'S. Average monthly minimum and maximum air temperatures average 5.5°C and 3.4°C lower, respectively, at the Craigieburn site than at Banks Peninsula. Days of snowfall at Craigieburn also exceed those of Banks Peninsula. Average yearly snow days for Craigieburn were 38.9 for the period of 1964-1980 whilst snow falls on Banks Peninsula on only 2.0 days per annum (period 1934-1980). Furthermore, frost days are frequent between April and November at the Craigieburn site, representing 8 out of the 12 months with ground frosts. In contrast, ground frosts begin later on Banks Peninsula and only become significant for the 5 months between May and September.

EXPERIMENTAL PROTOCOL

CTMin of eight field acclimatized geckos collected fresh from the field from each population were measured during midsummer (January) and midwinter (July) 1991. In addition, the effect of laboratory acclimation was tested as follows: twenty summer collected geckos from each population were divided into acclimation groups of 8 animals (4 animals for Craigieburn geckos acclimated at 5°C for four months) each consisting of comparable sized individuals. Three acclimation procedures were used: acclimation to 5°C for one month, 5°C for four months, and 25°C for one month. During acclimation, geckos were fed a yeast-honey mixture and water *ad libitum*, and subjected to a 12L:12D light regime. Freshly caught geckos were also housed in this manner before experimentation.

All experiments began within 7 days of collection (freshly caught animals), or immediately after the acclimation period in the laboratory. Animals were starved for two days prior to the commencement of experiments. CTMin tests were conducted between 1200 h and 1600 h in order to minimise the effect of any potential circadian rhythm in cold tolerance (Spellerberg & Hoffman 1972).

To inhibit excessive movement, animals were chilled to 5°C for 30 minutes prior to the start of an experiment, and then placed in a glass crystallizing dish (10 cm diameter, 6 cm high) on ice where cooling continued in a controlled manner. A small ice-pack was also lowered on top of the animals, and a thin layer of paper was placed in the bottom of the chamber to provide insulation so that body temperature fell at a rate of approximately 1.0°C min^{-1} (as recommended by Hutchison (1961) and Spellerberg (1973)). Animals were not handled until they became sluggish. At this point a fine thermocouple was inserted into the cloaca and the animal was returned to the cooling chamber. Body temperature was monitored via a digital readout, care being taken not to impede body movements with instrumentation (see Spellerberg 1973). Test animals were prodded on their flanks every two minutes and any locomotory ability was recorded. They were also flipped onto their backs and the presence of a righting response scored, the loss of which was taken to be the CTMin as suggested by Jacobson & Whitford (1970). One assessment of CTMin was made for each animal, after which they were allowed to recover. Since geckos may feign immobilization when rapidly turned on their backs, individuals that failed to right themselves were stimulated by moving the probe lead, and by touching their sides with a paint brush.

STATISTICAL ANALYSIS

Preliminary analysis of five treatments for which body mass was known showed no significant correlation between CTMin and body mass ($P>0.05$). Thus, body mass was excluded as a potential covariate of CTMin. Analysis of Variance (ANOVA) was used to compare CTMin between populations and treatments (for both acclimatized and acclimated geckos). For the acclimatization ANOVA, n

values are as shown in Figure 1A. However for the acclimation ANOVA the 5 replicates for Craigieburn geckos acclimated to 5°C for four months was balanced by randomly selecting 5 CTMin from the 8 total for all other cases. Variances were tested for homogeneity using Bartlett's Test. No data transformation was required for the acclimatization ANOVA ($P<0.05$). For the acclimation ANOVA the data was square root transformed to homogenise variances. ($P<0.05$, n=5). Student-Newman-Keuls procedure was used to determine significance following ANOVA (n values as in Figure 1).

RESULTS

BEHAVIOUR

During the first few minutes in the cooling chamber all geckos assumed a hunched posture with the back raised. When the thermistor probe was inserted into the cloaca geckos often emitted soft chirping vocalisations followed by body twisting using the tail as a propeller, and gaping of the mouth. When CTMin was reached, limb movement was shaky, but coordinated movements were restored within five minutes after experimentation.

ACCLIMATIZATION

No significant difference in CTMin was found between populations (ANOVA; $F_{[1,28]}=0.1$, $P>0.05$). However, the effect of treatment (*ie.*, season) on CTMin was highly significant (ANOVA; $F_{[1,28]}=39.1$, $P<0.05$) (Figure 1A). A significant interaction effect was found between acclimatization treatment and population (ANOVA; $F_{[1,28]}=3.5$, $P<0.05$). Thus, the

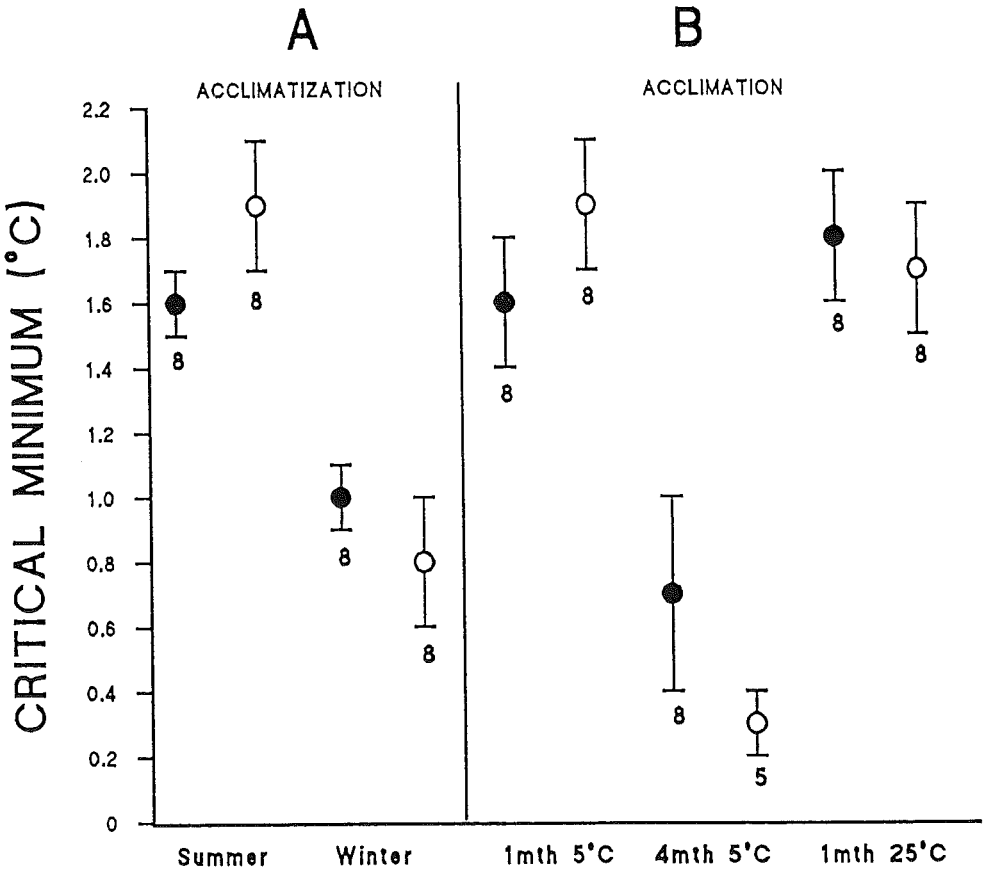

Figure 1. Critical Minimum body temperatures for Craigieburn (open circles) and Banks Peninsula (closed circles) geckos following A: collection from the field (acclimatization), or B: laboratory acclimation using 3 procedures (mean ±SEM, n value as shown).

winter CTMin value for Craigieburn was lower than the corresponding winter value for Banks Peninsula, whereas the situation was reversed in summer collected animals (Figure 1A).

ACCLIMATION

No significant difference in CTMin was found between populations in the acclimation experiment (ANOVA, $F_{[1,24]}=0.19$, $P>0.05$; Figure 1B). However, acclimation time significantly affected CTMin of Craigieburn geckos, which was 1.6°C lower after 4 months exposure to 5°C than after 1 month exposure to 5°C (ANOVA; $F_{[2,24]}=11.68$, $P<0.001$). CTMin of geckos acclimated for 1 month at 5°C did not differ from that of geckos acclimated for 1 month at 25°C (Student-Newman-Keuls procedure, $P>0.05$).

DISCUSSION

No difference in the CTMin of Craigieburn and Banks Peninsula populations was detected in this study. However, CTMin was significantly lowered by winter acclimatization and long-term acclimation (4 months) to cold (5°C) temperature. This apparently 'slow rate of acclimation' reached after four months has also been shown for preferred body temperatures (Tocher 1992b) and activity patterns (Tocher 1992a) for *Hoplodactylus maculatus*. As far as this author is aware, the CTMins of Craigieburn geckos following 5°C acclimation for four months (0°C-0.6°C) are the lowest values for CTMin recorded for any lizard species. For Banks Peninsula geckos CTMin was also low following this acclimation regime (0°C-1.8°C), thus indicating *H. maculatus* to be a cold-adapted species.

During the one month and four month acclimation periods at 5°C, geckos moved about within their enclosure and fed. Physiological performance was not seriously impaired and geckos were able to right themselves at temperatures much lower than 5°C. Spellerberg (1972) found that the greatest rate and range of acclimation of CTMin occurred at body temperatures 1°C below initial 'field collected' CTMin values. Summer CTMin values were 1.5°C-2.0°C for *H. maculatus* (Figure 1A). With this in mind, it is perhaps not surprising that the rate of acclimation was slow when geckos were held at 5°C. Furthermore, a fluctuating thermal environment such as that experienced naturally during winter, may be needed to accelerate acclimation processes (day-length may also be an important factor, [Bennett & Dawson 1976]). This could be reflected in the lower CTMin of winter collected geckos. Thus, it appears that conditioning for one month at 5°C was not enough to elicit changes in CTMin. Lack of CTMin acclimation within one month, followed by acclimation after 4 months, presents important considerations for the experimental protocol employed in future reptilian physiological studies.

The "ultimate" CTMin is that obtained after low temperature acclimation, preferably at an acclimation temperature slightly below the CTMin of summer animals (*ie.*, less than 1.6-2.0°C for *Hoplodactylus maculatus*) (Spellerberg 1971, 1976). Conversely, "incipient" CTMin is that occurring after warm acclimation to a temperature that is ecologically realistic to the species in question. I found that CTMin analogous, perhaps, to the ultimate CTMin may be obtained by acclimation to moderately low temperatures for a prolonged period (5°C for four months). Use of such an acclimation procedure may be more ecologically realistic at high latitudes than that suggested by Spellerberg (1971). Within deep retreats characteristic of winter hibernacula, temperatures may not even fall to the CTMin level of summer animals because of the insulating effect of deep snow cover.

Incipient CTMin (after acclimation to 25°C) was similar for individuals from both populations, and closely approximated the CTMin of freshly caught summer animals. Craigieburn geckos had an acclimation range (incipient-ultimate) of 1.4°C, whereas that of Banks Peninsula geckos was 1.1°C. Although a small difference, the lower variation observed for Craigieburn individuals (see SEM, Figure 1B) may indicate that they have more finely tuned acclimatory abilities.

The occurrence of a more labile CTMin is likely to advantage reptiles living in harsh and unpredictable environments. Indeed, seasonal differences and changes in CTMin with acclimation as shown here for *H. maculatus* are important adaptations to low environmental temperatures (Spellerberg 1976, Gregory 1982). For instance, possession of a low CTMin in spring will be advantageous to a reptile in a temperate climatic region or high altitude zone where sudden falls in temperature can result in high mortality (Spellerberg 1976 calls this 'emergence mortality'). On this basis, one might expect Craigieburn geckos to have a greater acclimatory

capacity and predictability of response than those from Banks Peninsula, but results from this study lend only limited support to this hypothesis.

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